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Response of plant functional traits during the restoration of calcareous grasslands from forest stands

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ABSTRACT

In this survey, we studied the response of plant functional traits to calcareous grassland restoration in the Calestienne region, Southern Belgium (restoration protocol: forest clear-cutting followed by grazing at all sites). We considered traits related to dispersal, establishment, and persistence that integrate the main challenges of plants to re-establish and survive in restored areas. Functional traits were compiled from databases and compared among (i) pre-restoration and young restoration forests; (ii) restoration areas of different ages; and (iii) old restorations and reference grasslands. The following questions were addressed: (i) What is the early response (2–4 years) in terms of plant functional trait following one restorative clear-cut event? (ii) What plants functional trait responses occur from restorative management (*i.e.*, sheep and goat grazing)? (iii) Which differences still persist between the oldest restored parcels (10–15 years), and the historical reference grasslands? Forest clear-cuts induced several changes among functional traits, including decreased mean seed mass and certain vegetative traits (*i.e.*, decreased phanerophytes, branching species; and increased short lifespan species *i.e.*, annuals and biennials). During restorative management, clonal, epizoochorous and autumn germinating species were favored. Despite numerous other changes during this phase, many differences remained compared to reference grasslands. In particular, geophytes, mycorrhizal and evergreen species abundance were not approaching reference grassland values. The observed pattern helped to draw inferences on the possible mechanisms operating under vegetation recovery following restorative forest clear-cut and subsequent management were identified and described in this study. Results indicated grazing was an important factor, which increased epizoochorous species, and autumn germinating taxa that filled niches in vegetation opened by summer grazing animals. Finally, differences between old restoration and reference grasslands emphasized that management should focus on reduction in soil fertility, and geophyte rhizomatous grasses. Long-term monitoring is vital to assess if management plans are effective in the complete restoration of species functional trait assemblages.

1. Introduction

Semi-natural calcareous grasslands historically developed across Europe from sheep-grazing practices, resulting in unique, species-rich habitats (Korneck et al., 1998; WallisDeVries et al., 2002). They had their maximum extensions during the Roman period, the Medieval age and the early Modern Times (Poschlod and Baumann, 2010; Poschlod et al., 2008), but locally also starting from the Neolithic age on (Dutoit et al., 2009). Since the end of the 19th century, semi-natural calcareous grasslands have undergone dramatic decline and fragmentation in European countries (Krauss et al., 2010; Piqueray et al., 2011c; WallisDeVries et al., 2002). Following abandonment of traditional agro-pastoral practices that were responsible for their maintenance, these unique communities were replaced by arable land, afforestations, or spontaneous encroachment and succession from adjacent forest communities (Poschlod and WallisDeVries, 2002). In Belgium, over 90% of

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calcareous grasslands have been lost since the 19th century (Adriaens et al., 2006; Bisteau and Mahy, 2005; Piqueray et al., 2011a). A large proportion were afforested at the end of the 19th century with *Pinus sylvestris* L. and *Pinus nigra* Arnold. (Vandermotten and Decroly, 1995). Other areas experienced natural successional processes following grazing abandonment, and were progressively replaced by oak woodlands. The maintenance and enhancement of calcareous grassland networks is now recognized as a priority in European biodiversity conservation policies, as cited in the Habitat Directive 92/43/EEC (habitat type 6210). Therefore, since the 1990s restoration practices were applied to redevelop the grasslands, including clear-cutting of trees and shrubs, top-soil removal or cutting regimes to impoverish nutrients as well as sowing or hay spreading (Dzwonko and Loster, 2008; Edwards et al., 2007; Fagan et al., 2008; Hutchings and Stewart, 2002; *e.g.*, Kiefer and Poschlod, 1996; Kiehl et al., 2006; Piqueray et al., 2011b; Poschlod et al., 1998).

In many cases calcareous grassland restoration has been assessed using plant community responses such as diversity and/or species composition (*e.g.*, Karlík and Poschlod, 2009; Kiefer and Poschlod, 1996; Piqueray and Mahy, 2010; Ruiz-Jaen and Aide, 2005). These responses were in some cases related to local environmental conditions, but did not explicitly relate species recovery to ecological processes, and/or morphological and physiological mechanisms. Functional traits are a reasonable tool in this respect (Lewis et al., 2014; van Noordwijk et al., 2012). They can either be useful to determine effects of plants on ecosystem functions (effect traits) or to understand the response of plants to environmental changes such as disturbances (response traits) (Lavorel and Garnier, 2002). Among response traits, those reflecting dispersal, establishment, and persistence mechanisms integrate the main challenges of plants to survive and re-establish and may therefore play a considerable role in understanding and predicting changes in calcareous grassland composition and structure (Lavorel and Garnier, 2002; Poschlod et al., 2000; Weiher et al., 1999). They are also recognized as tools for the monitoring of grassland communities (Ansquer et al., 2009). Therefore, functional traits may be used to evaluate vegetation recovery during and following restoration (Poschlod et al., 1998, 2000; Weiher et al., 1999). By understanding how plant functional traits respond to ecological processes (*e.g.*, disturbance, natural succession following restoration), it becomes possible to predict what species assemblages might naturally occur or be successfully restored (Poschlod et al., 1998).

Plant community dynamics following species-rich grassland restoration from secondary forest or ecosystems by clear-cutting has seldom been studied from a functional point of view (but see, Dzwonko and Loster, 2007; Helsen et al., 2013). Dzwonko and Loster (2007) showed that traits related to establishment were a major driver of the plant success in restored grasslands. Also, dispersal traits both in space and time may be relevant for species success in restored habitats (Helsen et al., 2013; Poschlod et al., 1998). After several years, differences between restored and reference grasslands may still remain (see *e.g.*, Piqueray et al., 2011b; Zobel et al., 1996). However, this may depend on management practices following restoration, affecting trait composition of the successional stages after clear-cut (Kahmen and Poschlod, 2008b; Poschlod et al., 2000).

In this study, we analyzed the functional response of vascular plants to calcareous grassland restoration by woodland clear-cutting in the following set of questions: (i) What is the early response (2–4 years) in terms of plant functional trait following one restorative clear-cut event? (ii) What plants functional trait responses occur from restorative management (*i.e.*, sheep and goat grazing)? (iii) Have all functional traits been re-established in the oldest restored parcels (10–15 years), or do the traits still differ from historical reference grasslands?

2. Methods

2.1. Study sites and field surveys

The study area included two Belgian regions, the Viroin Valley, and the Lesse and Lomme Valleys, both located in Calestienne, a narrow Devonian limestone strip traversing Southwest to Northeast. Both regions support large expanses of grasslands, and are considered the most important regions for calcareous grassland conservation in Belgium. Different grassland communities occur within the two regions, with *Mesobromion* communities the most widespread. *Mesobromion* grasslands are semi-natural calcareous grasslands developing on gentle slopes or on plateaus, dominated by grasses such as *Bromus erectus* and *Brachypodium pinnatum*. They host the highest species richness among the calcareous grasslands communities occurring in Belgium (Piqueray et al., 2007). Both regions have similar species pools (Butaye et al., 2005; Piqueray et al., 2007). They are separated by a distance of only 40 km and have similar land-use histories (Adriaens et al., 2006; Piqueray et al., 2011c). Due to the large-scale loss of these ecosystems throughout Belgium, more than 100 ha of calcareous grasslands (*ca.* equivalent to the remaining surface) have been restored over the last 25 years in the study area. All restored sites were derived from 40–100 year old forests established on former calcareous grasslands. Restoration protocols included tree and shrub clearing, followed by sheep and goat grazing (André and Vandendorpel, 2004; Delescaille, 2006; Graux, 2004).

Eight sites, four in the Viroin Valley and four in the Lesse and Lomme Valleys were selected for the present study (Table 1). The eight study sites support old grasslands, as well as afforested abandoned grasslands. At each site, some afforested parcels were clear-cut in grassland restoration efforts.

Since 2003, all sites have been managed by grazing using migrating sheep flocks (duration: 2–3 weeks/year, resulting to a grazing intensity of 1–2 sheep/ha × year; restored parcels are grazed each year, reference parcels every 2 or 3 years depending on site) (Piqueray et al., 2013).

We conducted thorough analyses of historical maps, aerial photographs, and ground field surveys and identified 28 parcels (2–5 per site) representing a range of grassland conditions (Table 1). In particular we selected the following:

(1) Reference parcels ($n = 8$, four per region). Calcareous grasslands reported as undisturbed historic sites, in existence for more than two centuries. They harbor *Mesobromion* plant community. This is considered the reference ecosystem for restoration purposes.

(2)Restored parcels ($n = 12$, six per region). Afforested abandoned grasslands, recently (*i.e.*, in the last 15 years) clear-cut forests managed primarily through grazing for grassland restoration. The time elapsed since restorative clear-cut (in years) was known for each restored parcel. The parcels were chosen to be representative of three age classes since restoration: 2–4 years, 5–8 years, and 10–15 years; 4 parcels per age class, 2 per region. Six of the parcels were restored from pine stands, and six from oak coppices. *P. nigra* or *P. sylvestris* plantation stands were aged up to 100 years. The species composition of dense shrub oak coppices (>40 years old) primarily included *Prunus spinosa, Crataegus monogyna* and *Corylus avellana*, with sparsely intermingled *Quercus robur* trees. Clear-cut included elimination of trees and shrubs, but tree stumps remained.

(3) Forest parcels ($n = 8$, four per region). Forests established at least 40 years ago on former grasslands.

Mesobromion grasslands (reference parcels) and forest parcels were adjacent to restored parcels under similar topographic conditions. Floristic surveys and species cover (%) were recorded in 20 1 m^2 quadrats in each restored parcel, *i.e.*, total number of quadrats was 80 per age class. Quadrats were located in cardinal